Case study no. 3

"RAABSTEG" FELDBACH (A)

1. General information

Type of building	(Covered) Pedestrian and bicycle bridge
Structural system	Cable supported single-span girder with suspended bridge deck
Owner	City of Feldbach / Styria (A)
Location	Feldbach / Styria (A)
Used Materials (for the main structural parts) - Abutment and pylons - Deck - Columns - Tension bars - Suspension cable - Deck surface	 Concrete C30/37 CLT-Elements glued with asymmetrically combined glulam beams (GL36c) acting as a T-section; wood species: Spruce Glulam GL24h; wood species: Larch Steel S235 Steel S235 Mastic asphalt
Erection date	08 / 1998
Investor	City of Feldbach and Government of the Province of Styria (A)
Architectural, structural and construction design	Lignum Consult / Graz (A) BM Ing. K. Angerer, DI J. Riebenbauer Collaboration: M. Augustin
Consultant Timber Engineering	Univ.-Prof. DI Dr. techn. G. Schickhofer / Graz (A)
Construction Companies: - Abutment - End columns - Timber structures - Mastic asphalt	 City of Feldbach / Styria (A) Fa. Lieb-Bau-Süd GmbH & Co KG, Gleisdorf (A) Fa. Stingl GmbH, Trofaiach (A) Fa. Swietelsky, Feldbach (A)
Price - Abutment - Structure (incl. railing and superstructural parts) - Cost per square meter traffic area	 € 23.255,- € 118.457,- € / m²: 1.138,-

2. Investment design

City development purposes caused the bridging of the river Raab by a pedestrian and bicycle bridge in the eastern part of the city of Feldbach in the austrian province of Styria. In this area the river Raab has a width of about 20 m. The bridge connects the centre of the town with the new raised Centre for Healthiness and Culture and contributes to the expansion of the local bicycle network.

To find an appropriate solution for the given location three variants have been designed and analysed by students of Graz University of Technology, Faculty of Civil Engineering – a suspension structure, a fish-bellied girder and a cable supported plate – and have been presented in February 1997 to the major and some communal representatives.

Rapidly the discussion came to the result to build the present variant of a cable supported single-span girder with a suspended traffic deck (Fig. 1). After the detailed design and the clarification of the financing concept the bridge has been erected in August 1998 and could be given over to the traffic already one month later.

Fig. 1 Pedestrian and bicycle bridge „Raabsteg“ in Feldbach (A)

3. Structural system

The structural system of the roofed “Raabsteg” bridge is a cable supported single-span girder with a suspended traffic deck and a free span of 35,0 m and a clear width of 2,50 m (Fig. 2 and 3).

The bridge deck is composed of a cross-laminated timber plate (CLT-plate) which transfers the actions to glulam-beams at the edge of the plate. Those beams are glued with the CLT-plate so that the deck has the function of a T-beam.

Exactly the same structural system has been chosen for the roof construction to act as a stiffening beam for the tension chord. The BS18k-girder (GL36c in accord. to EN 1995) – an asymmetrical combined glulam-beam of the highest strength class in accordance to the Austrian National Standard at the time of erection – of the roof rests on the four bearing-areas consisting of reinforced concrete pylons, which lead the vertical and horizontal loads from the roof plane into the abutment.

Both the upper and the lower deck are manufactured with the wood species spruce.

Dead and traffic loads acting on the surface of the traffic deck are conducted by tension bars (ISTOR TX55) into the tension chord, further into the bearing points of the pylons and the upper plate respectively. The roof T-beam is loaded in compression and bending and is jointed with the road surface by vertical larch glulam-columns. The greater part of the roof-deck's dead load is carried in this way by the lower deck and loads are leaded further to the tension tie. Furthermore the columns are acting as lateral supports for the stiffening beam of the roof deck.

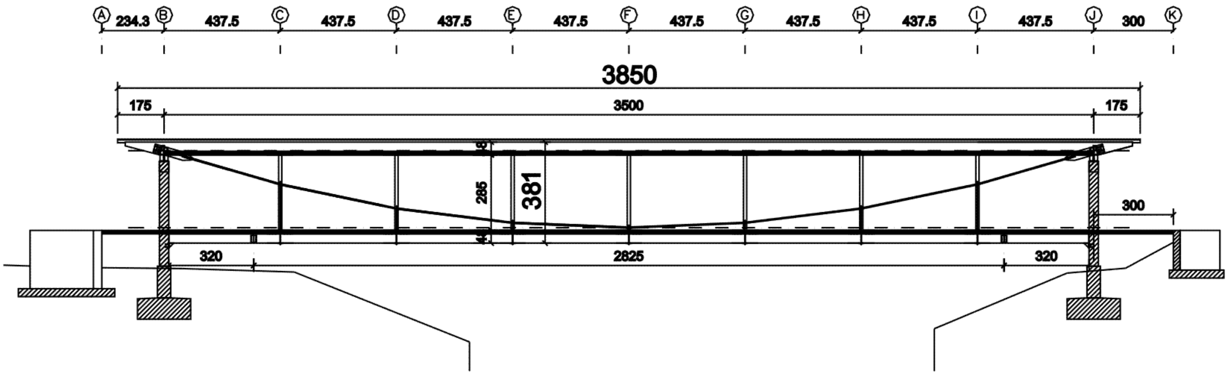

Fig. 2 Longitudinal section and structural system of pedestrian bridge „Raabsteg" in Feldbach (A)

The cross-section of the bridge shows a structure clearance of 2,58 m width and 2,80 m height. It allows the crossing of vehicles for maintenance purposes up to a load of 6,6 tons. The roof and the traffic deck are consisting of two (twin-) glulam beams (200/350 mm; 200/480 mm). The deck is formed by a 135 mm thick 5-layered CLT-plate glued with both glulam beams and is therefore acting as a T-beam.

The upper deck system, which sustains the roof, has been designed and produced in the same way as the lower plate is also glued with two BS18k-twin beams (GL36c) at the edges of the plate. The tension bars (steel Ø24 mm) conduct the loads from the lower deck-plate into the tension chord (flat steel 40/200 mm, ST 510 C). To perform an upper completion of the roof a slightly curved three-layer wood panel with a sheet metal is responsible for the lead-away of rain and snow.

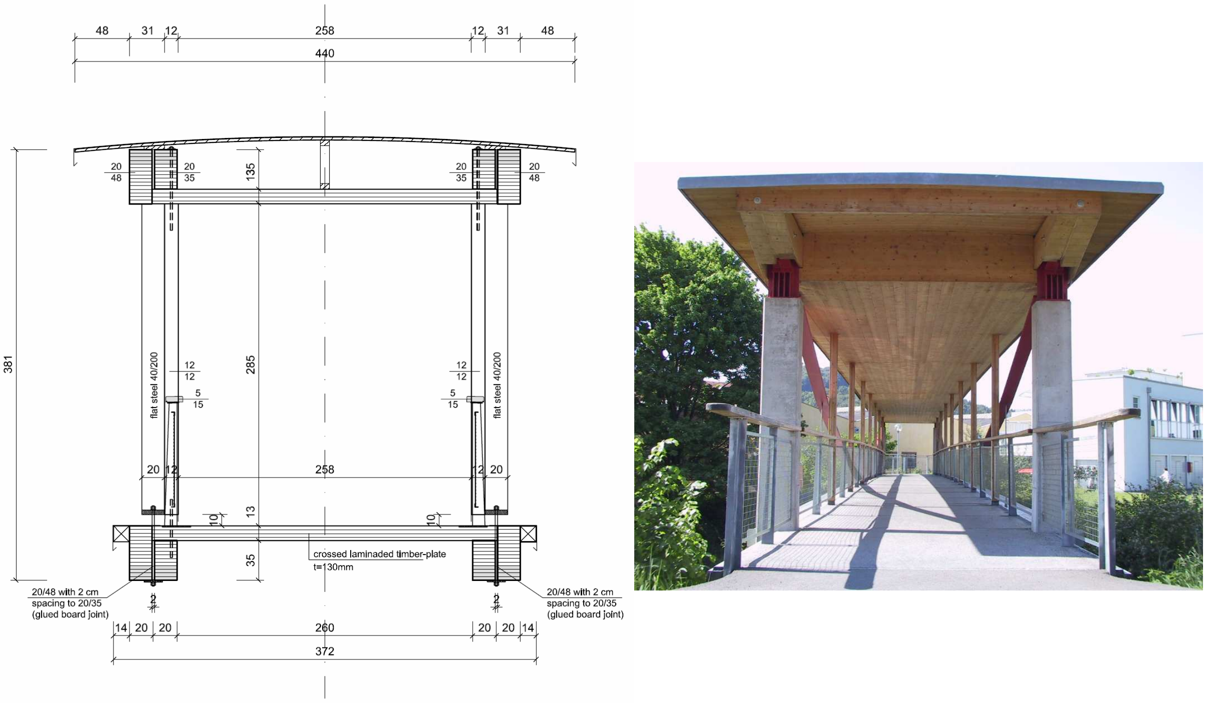

Fig. 3 Cross-section

4. Computational models used

Structural analysis has been done with the programme package “APL” (developed by Zenkner and Handel, Graz (A)) which allows the analysis of structural systems using Theory of 2. Order. All calculations have been carried out with the planar structural system given in Fig. 4.

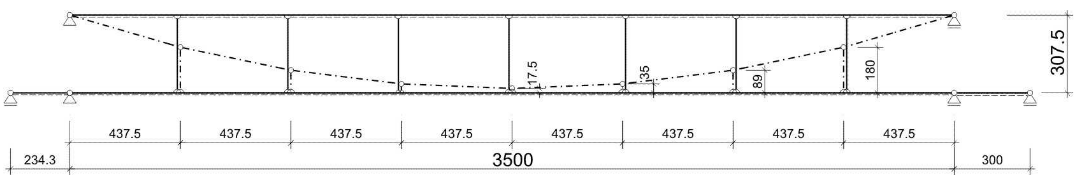

Fig. 4 Structural system

Analysis work showed that the mechanical behavior of this kind of structural system is dominated by the stiffness of the tie bar. As a consequence serviceability limit states (deformation, vibration) has been decisive for the design during the optimization prozess. For the design of the columns apart from their load carrying capacity an adequate stiffness to reach the second eigenform for the roof member has been considered.

Vibration analysis has been also done on the planar system. The calculated eigenfrequency during the design of about 3 Hz has been checked by in-situ test which resulted in a good conformity with the results from the analysis.

5. Actions on structures

The Austrian Standard ÖNORM B 4002 which has been valid at the time of the design of the bridge is providing a basis for the design actions. The load specifications in longitudinal direction are listed in the following table (Tab. 1).

dead load	deck-plate roof-plate	g_1 g_2	6,3 3,7	kN/m kN/m
snow		s	0,85	kN/m²
traffic load	uniformly distributed load vehicle for maintenance puposes	p_k P_k	5,0 66,0	kN/m² kN

Tab. 1 Design Actions

The relevant load case is reached by full load (dead load, traffic load, snow). The design forces have been calculated by means of a computer program and are shown in Tab. 2.

	N_{min}	N_{max}	$M_{y,max}$	$M_{z,max}$	V_{max}	H_{max}
roof-plate	-939,7 kN		92,5 kNm	189,9 kNm		
column	-34,4 kN					
upper support					155,9 kN	10,9 kN
tie bar		978,5 kN				
deck-plate			100,9 kNm	346,1 kNm		
suspension post		88,8 kN				
lower support					46,8 kN	19,8 kN

Tab. 2 Design loads for the main members of the bridge

6. Project documentation, plans, and drawings

Plans and drawings of the “Raabsteg Feldbach” are given in Fig. 2, 3 and 4.

7. Erection

The bridge has been prefabricated and compiled in the production hall of the timber construction company Stingl GesmbH in Trofaiach (A) and has then been transported by means of a low loading trailer all-in-one piece from Trofaiach to Feldbach (A) (about 130 km distance). On-site the structure has been attached on the pylons by means of three mobile cranes. Finally the roof membrane, the coating of the deck and the pipes for the district heat and electricity cables have been mounted.

Fig. 5 Transportation of the bridge

Fig. 6 Assembly of the bridge

8. Interesting construction details

8.1. Deck Construction

The deck is glued with both glulam- (twin-) beams at the edge of the CLT-plate and has therefore the function of a T-beam. For the lay-up a five-layer crossed laminated timber-plate (17/32/32/32/17 mm) made by the company Stingl, with a thickness of 13 cm. On the upper surface of the deck a two layer sealing and on it a 5 cm mastic asphalt layer as mechanical protective layer and weathering coat (Fig. 6) has been applied.

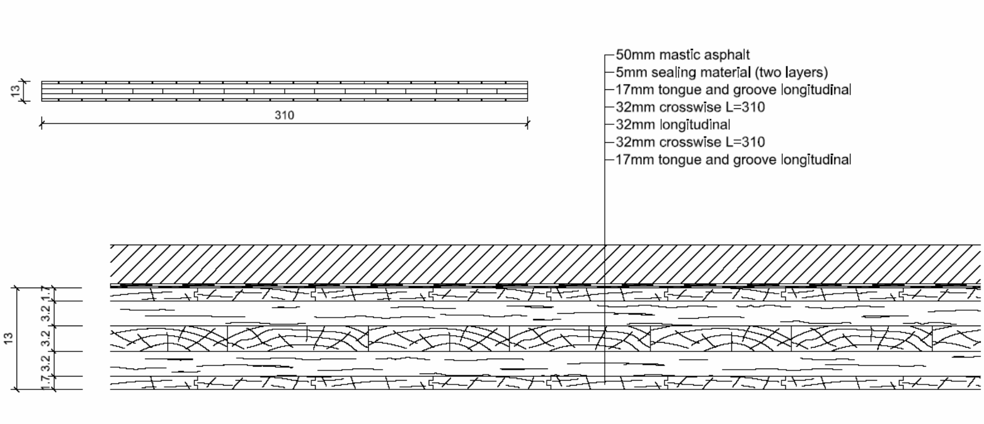

Fig. 7 Cross-section of the deck-plate

8.2. Connection Suspension Bar on Main Girder

To connect the glulam-columns (larch) with the decks a steel-plate angle has been slotted into the column and has been connected by means of steel dowels and wood screws respectively. The tension bars are arranged in the center of the twin glulam-beams and were inserted trough them to load them on compression perpendicular to the grain at the lower side by means of a steel plate and threads with nuts. On the upper side a transverse steel pole with an inside thread has been welded on the tension tie. The point of penetration has been realized using a plug sleeve. To protect the main construction against driving rain a square-sawn timber on the outside of the gluelam beam has been screwed on them. Finally the edge area has been covered by a zinc sheet (Fig. 7).

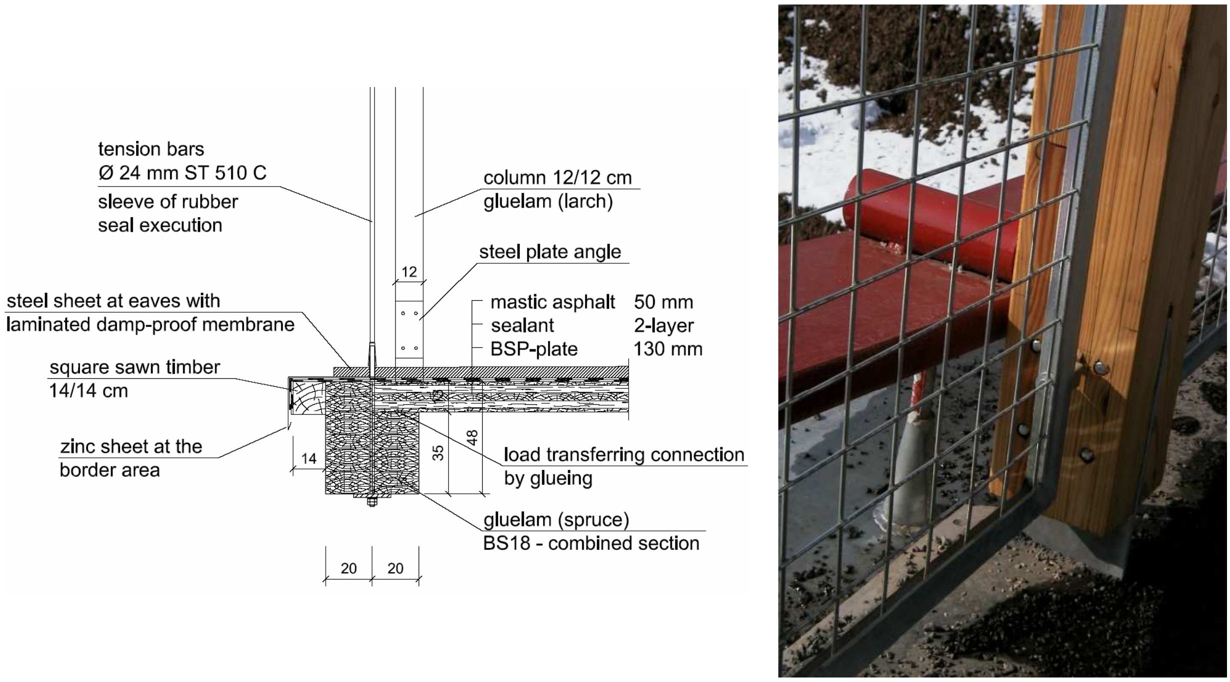

Fig. 8 Detail at the connection between the suspension bar the main girder

8.3. Support Detail – Connection Tie Bar

The tie bar consists of a flat (40/200 mm) of steel ST 360 C and has been welded with a steel sword, which leads the loads into a complex steel part. This part - which is connected with the supporting pylons by means of self-fixing screws - introduces longitudinal loads with a contact joint into the roof deck and is leading it's loads into the reinforced concrete columns (Fig. 8).

The final form of this detail has been already manufactured and mounted in the production hall of the manufacturer.

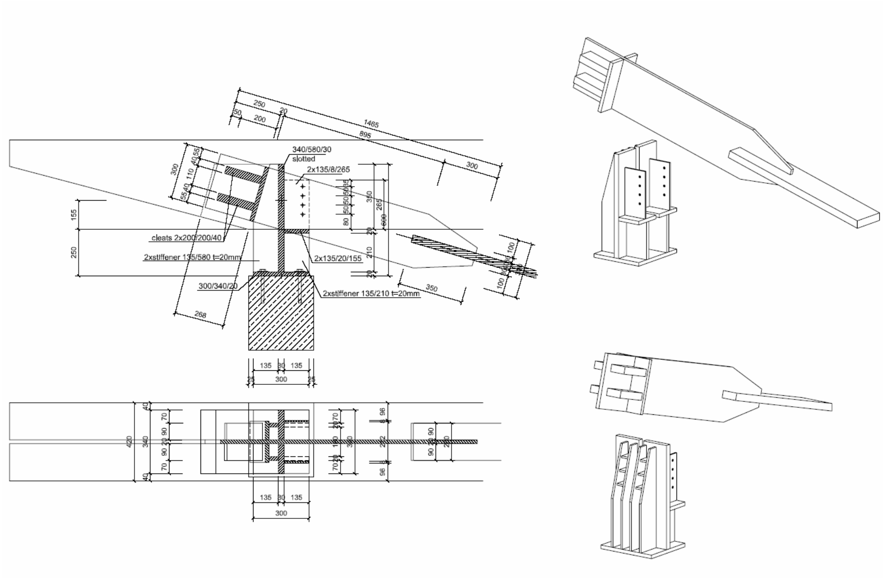

Fig. 9 Supporting detail

8.4. Railing System

The railing is made up of eight fields and is located between the sections of the columns. Single fields are separated on one hand by the timber columns and on the other hand by steel posts (ST 360 C). In the fields steel grids are situated which are welded on gentle steel angles and fixed with simple screw connections on the columns. The easy to change glulam (larch) handrail is forming the upper limit of the railing system (Fig. 8).

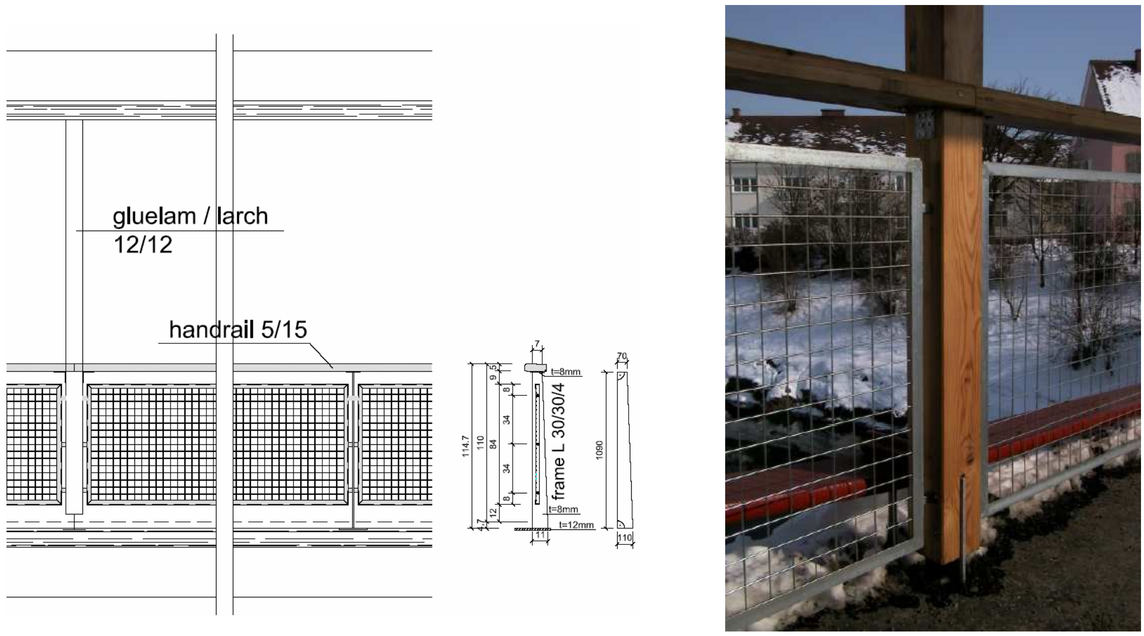

Fig. 10 Railing and protective construction

9. Protection from weather effects

During the design process of the structure primarily constructive principles of weather effect protection have been considered. Since the bridge is canopied the main protection from weather effects is done by the roof. In addition the twin glulam-beams of the traffic deck are protected by square-sawn structural timbers covered by a zinc sheet. The deck-plate has a two layered sealant with an slightly inclined 50 mm thick mastic asphalt layer. For the weather exposed columns and the handrail the resistant wood species larch has been used.

In addition all wooden parts were treated three times with the wood-preservative glaze “Danske Vakuummattype”.

The tension-tie which is highly exposed to rain and snow has been covered with a plumbiferous corrosion coating covered by a three times top painting. All other steel parts are provided with a zinc coating.

10. Economical and ecological aspects

From the economical point of view this bridge has been a relative cheap solution for the given challenge. Abutment and parts of the pylons have been manufactured by the owner. Since the bridge has been manufactured in the production hall of the producer for the production process the stationary equipment of the company (cranes, tools etc.) could be used. In comparison to an in-situ assembling of the load carrying members the costs of the 120 km transport between the production hall and the building site and the lifting to the end-position by means of three mobile cranes has been cheaper and more time effective.

Concerning to ecological aspects it has to be mentioned that about 2/3 of the province of Styria are covered with forests. Because of this the use of wood and timber but also because of the natural scenery in the city of Feldbach a wooden bridge was rated as the appropriate material for this building.

Instructions and case study no 3 were prepared by the Institute of Timber Engineering and Wood Technology at Graz University of Technology.